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Title: Technology Commercialization Fund (TCF): Hydrogen Contaminant Detector (HCD)

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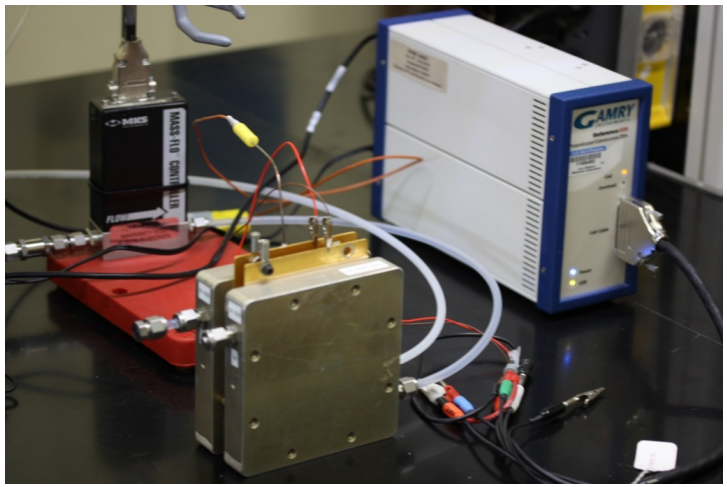
Technology Commercialization Fund (TCF)
Hydrogen Contaminant Detector (HCD)



Team:
Eric L. Brosha, Chris J. Romero, Tommy Rockward and Rangachary (Mukund) Mukundan

January 14th, 2021

Goals of Project

- Develop Commercialization Pathway for LANL HCD Technology
  - US Patent 10,490,833: Hydrogen Fuel Quality Analyzer with Self-humifying electrochemical cell and methods of testing fuel quality
    - Technology developed under Safety Codes and Standards program
    - Technology evaluated at H2Frontier station
  - Develop better hardware, electronics package for lower cost Gen II analyzer (LANL lead)
  - Develop Commercialization plan (Skyre Lead)

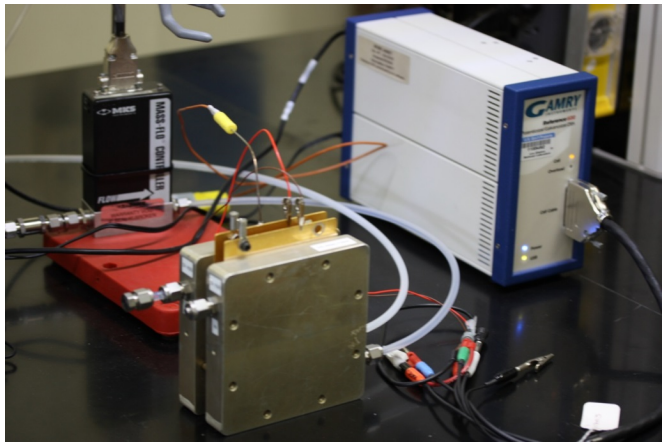
- Submit R&D 100 Application
  - Joint application with LANL (Eric Brosha lead), H2Frontier and Skyre
  - Selected as R&D100 Finalist in 2020

Photos taken at H2F filling station, Burbank CA.

Scope/Timeline

- 12 month project from Jan to Dec 2020. Extended till March of 2021. Cost share by Skyre. $150K of DOE TCF funds to LANL
- Hardware development
  - Currently uses FCT single cell 50cm^2 hardware, Cartridge heaters and controller, Mass flow controller
  - Custom build HCD with low cost hardware
- Electronics development
  - Currently uses a Gamry Reference 600$^+$ potentiostat, Full computer system with labview software to control HCD
  - Develop custom electronics and control
- Evaluation by Skyre ongoing
- Commercialization plan pending

Total laboratory test system cost here ~ $22.5K + computer system.



HCD Control Module Development - 1

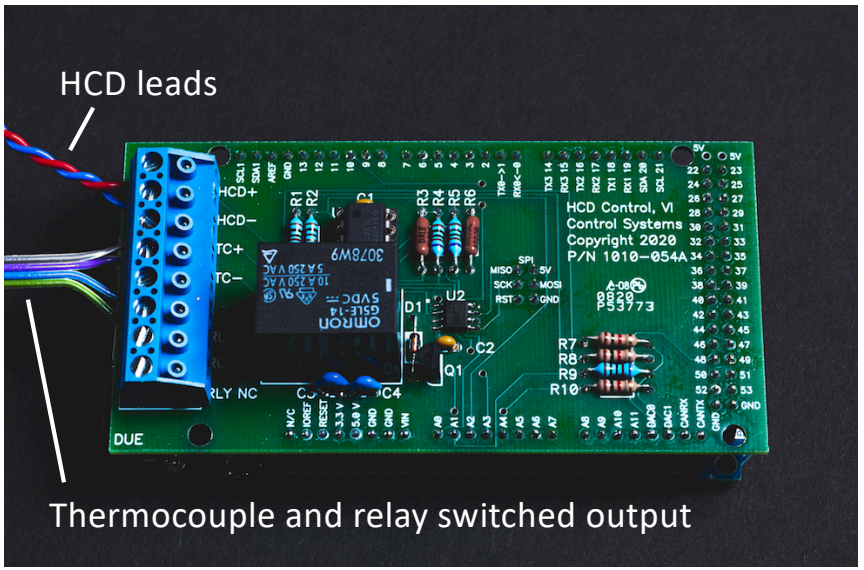
- Design and test a control module and software package to do what the Gamry presently does but at a fraction of the cost.
- Circuit must apply proton pumping voltages and clean-up cycles while logging current and HCD temperature.
- Use a current interrupt approach to measure a membrane resistance.
- Accept an alarm point to signal when H_2 fuel quality falls below spec.

- We selected VI Control Systems of Los Alamos as a design/development partner.
- Worked with VI Controls in previous NMSBA project.
- www.vicontrols.com

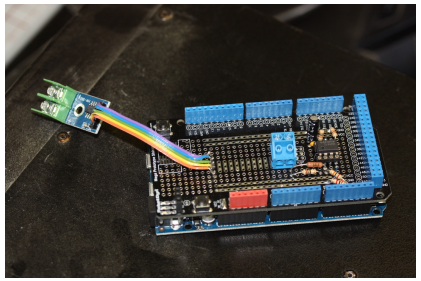
HCD Control Module Development - 2

- New control module based on Arduino architecture.
- **Arduino 32bit processor is only $50!**
- Uses 5V USB connection with data logging computer.
- Temperature chip uses type K thermocouple.
- Relay and MOSFET added for external control of H2Frontier E-stop system to shut down H_2 delivery to storage if CO rises above 200ppb from methane reformer system.
- Gen 1 version tested and improvements identified.
- 2 Beta test versions of control software evaluated.
- Current sale price from VI Controls is $2500.

Gen 2 Prototype

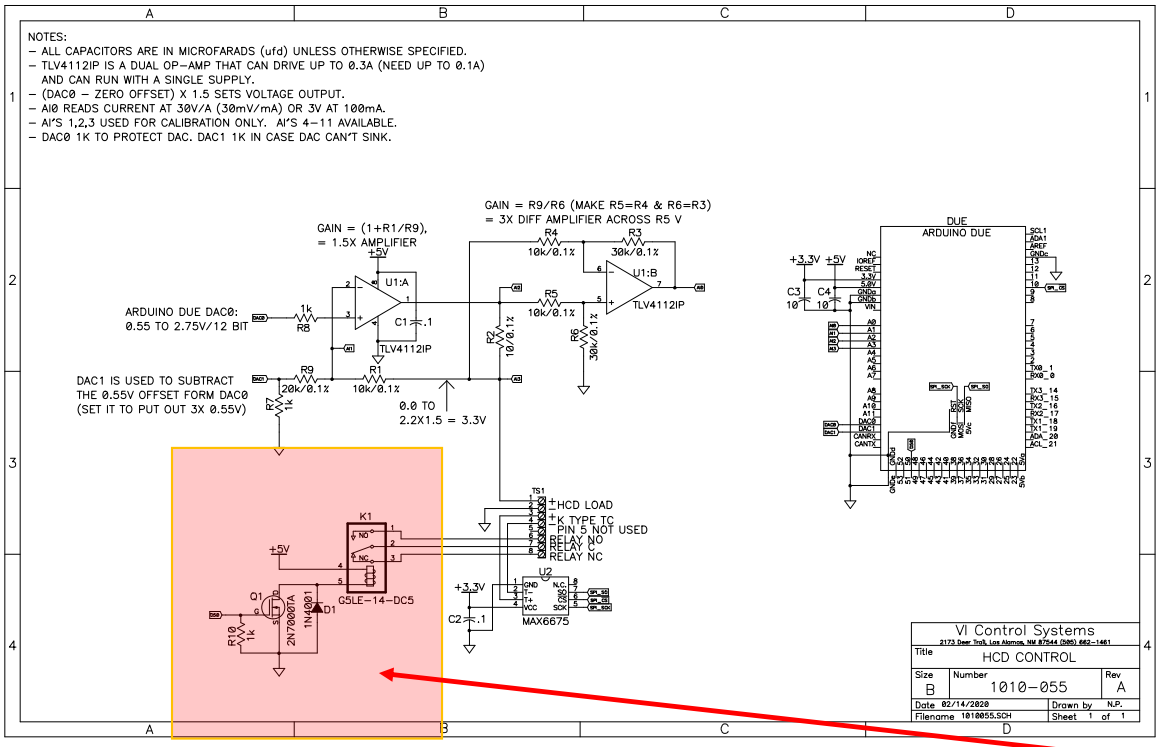


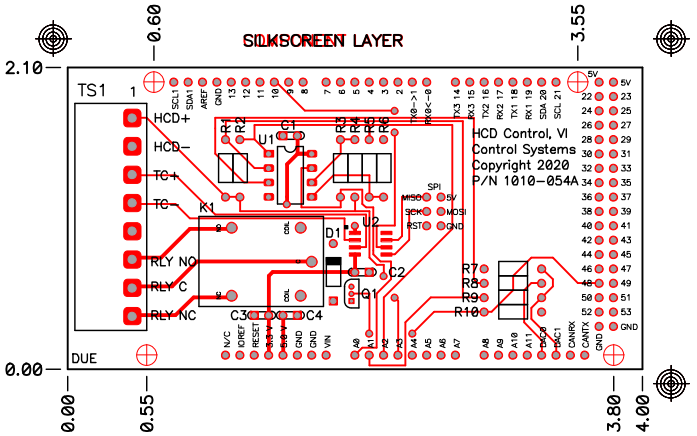
Gen 1 board for comparison.



“Gen 2” HCD Control Module Development

Simple circuit yet performs non-impedance functions of the Gamry 600+ with acceptable signal to noise.

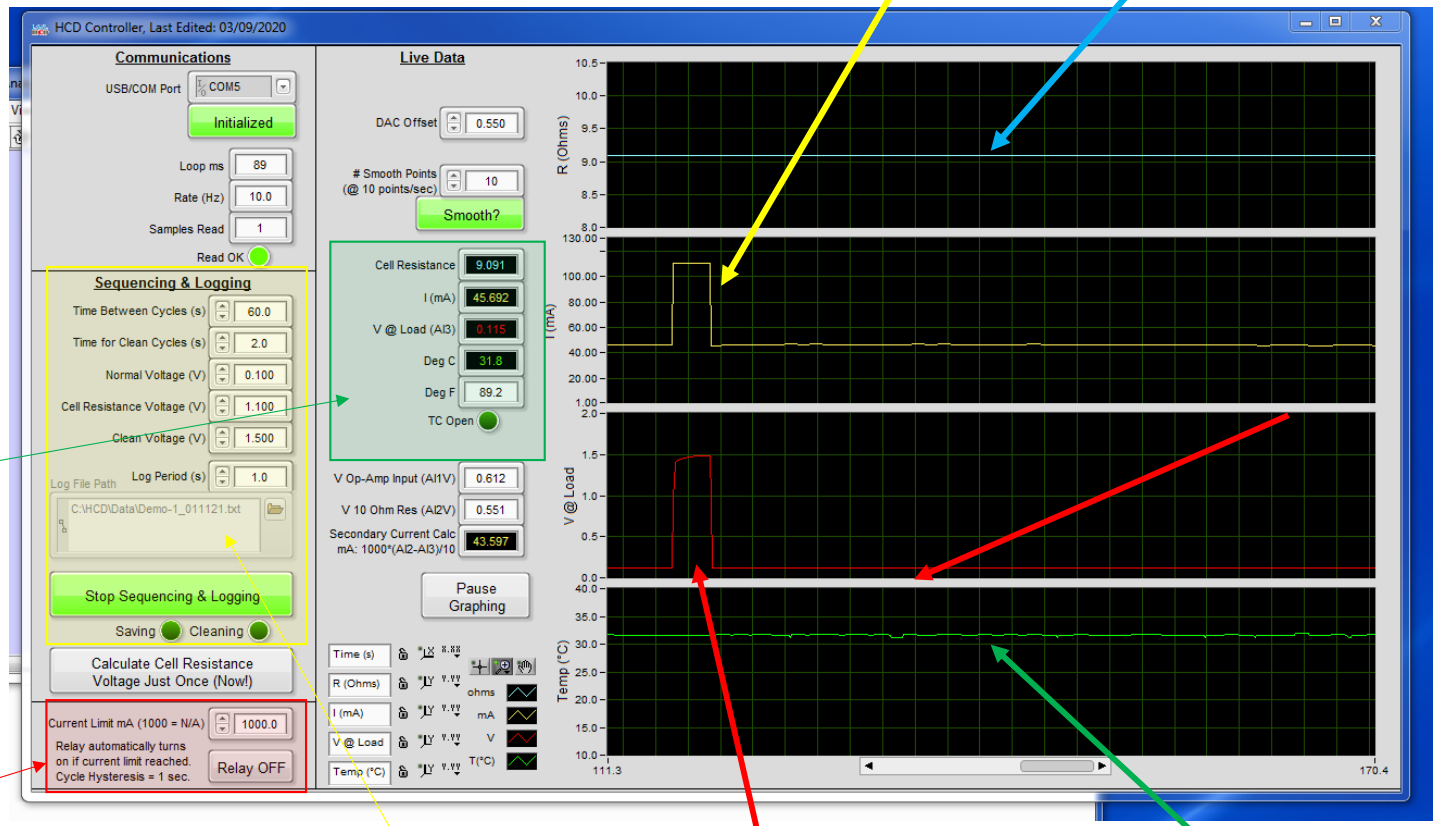




Accelerated introduction at the request of H2Frontier testing partner

HCD Application Testing; 2nd Beta test version

Screen shot of new VI front panel.



HCD current

Cell resistance

Real time data

Relay control – eStop interface setup

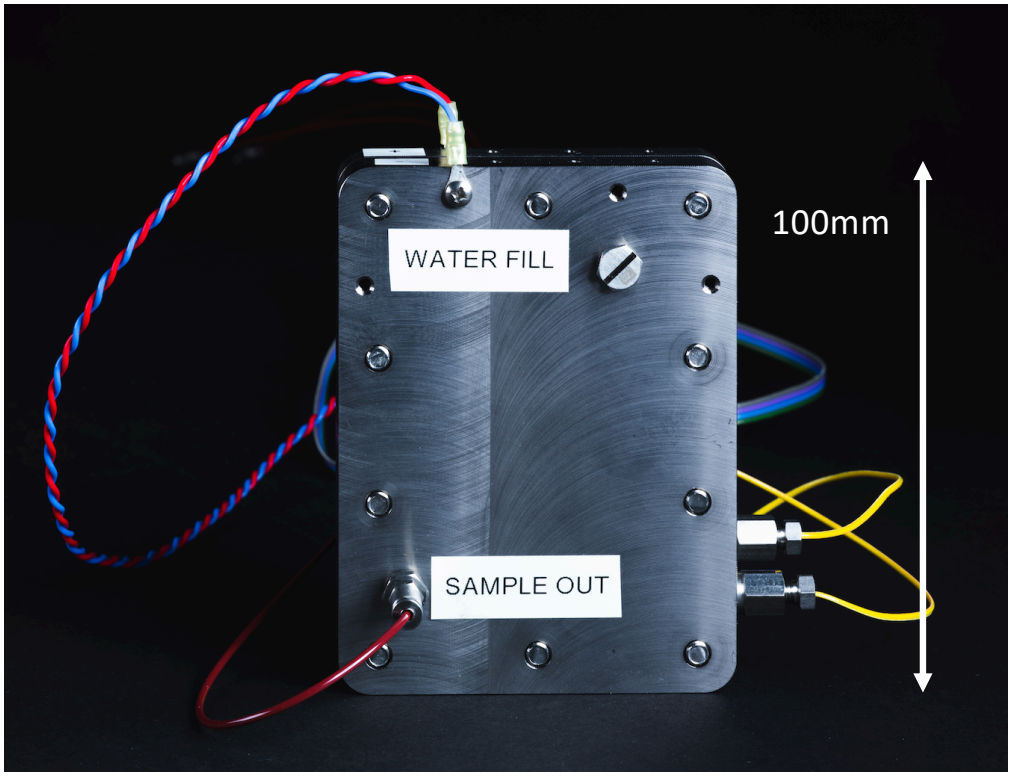
HCD protocol definitions

Clean up pulse

HCD temperature

Pre-commercial HCD significantly lowers build cost

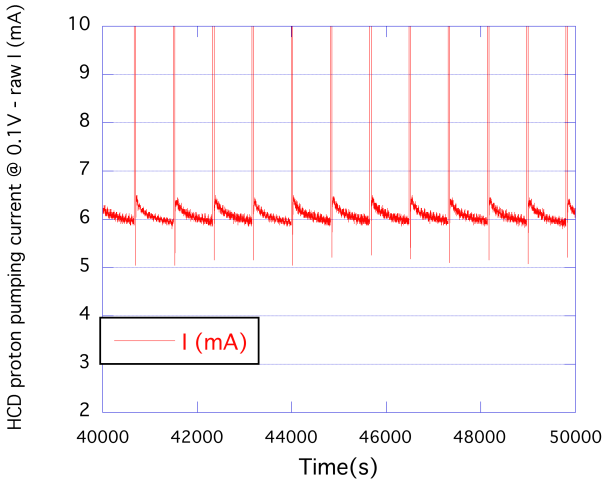
- Fuel Cell Technologies single cell fuel cell hardware previously HCD's used lists at ~$3500ea.
- With FCT hardware, new machined graphite flow field blocks required to accommodate unique sensor geometry and internal water reservoir. Additional ~$900 cost.
- New HCD hardware was designed and fabricated using corrosion resistant Titanium.
- Inexpensive: ~$400/set including material and labor.
- Internal water reservoir volume the same as the much larger HCD's tested in Burbank.

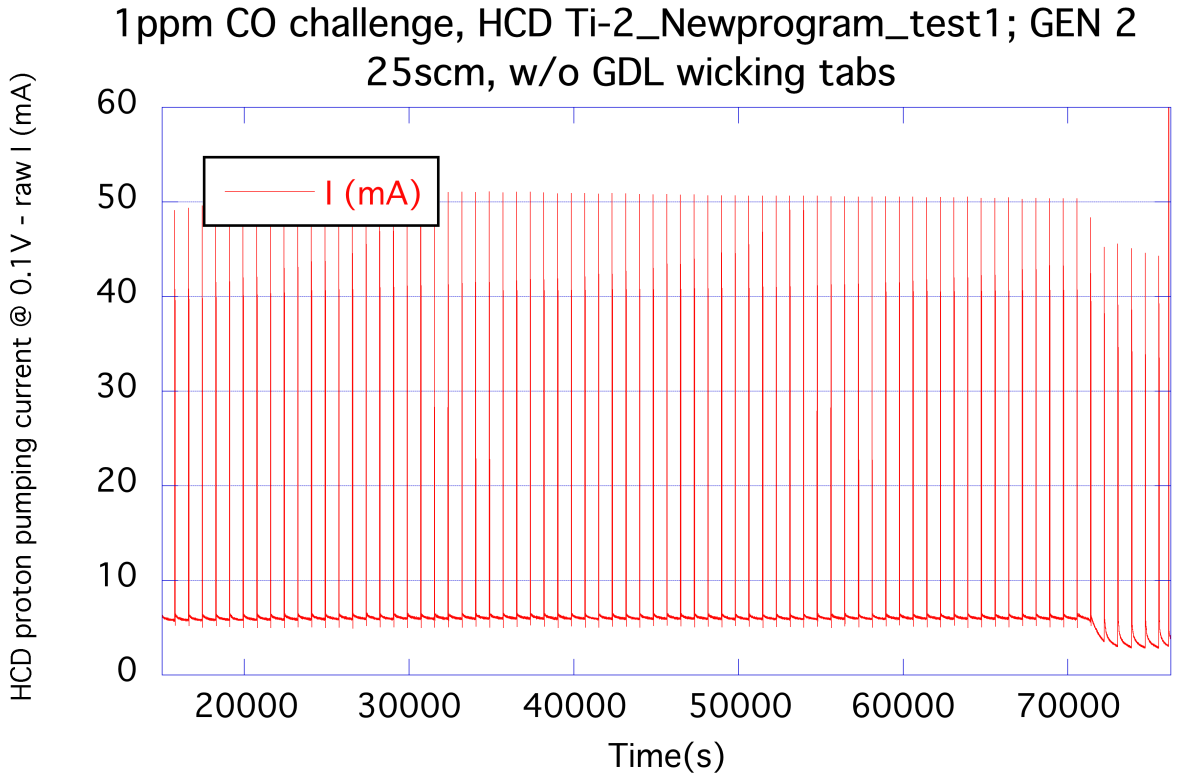


Still optimizing new GDL wicking tabs, ideal compression, etc.

Some testing results before xfer to Skyre

- HCD proton pumping current behavior is same as seen using expensive potentiostats.
- Data is more noisy – price paid for lowering electronics cost.
- HCD has stable baseline and responds to CO.
- Same characteristic slow loss of pumping current in between clean-up voltages.





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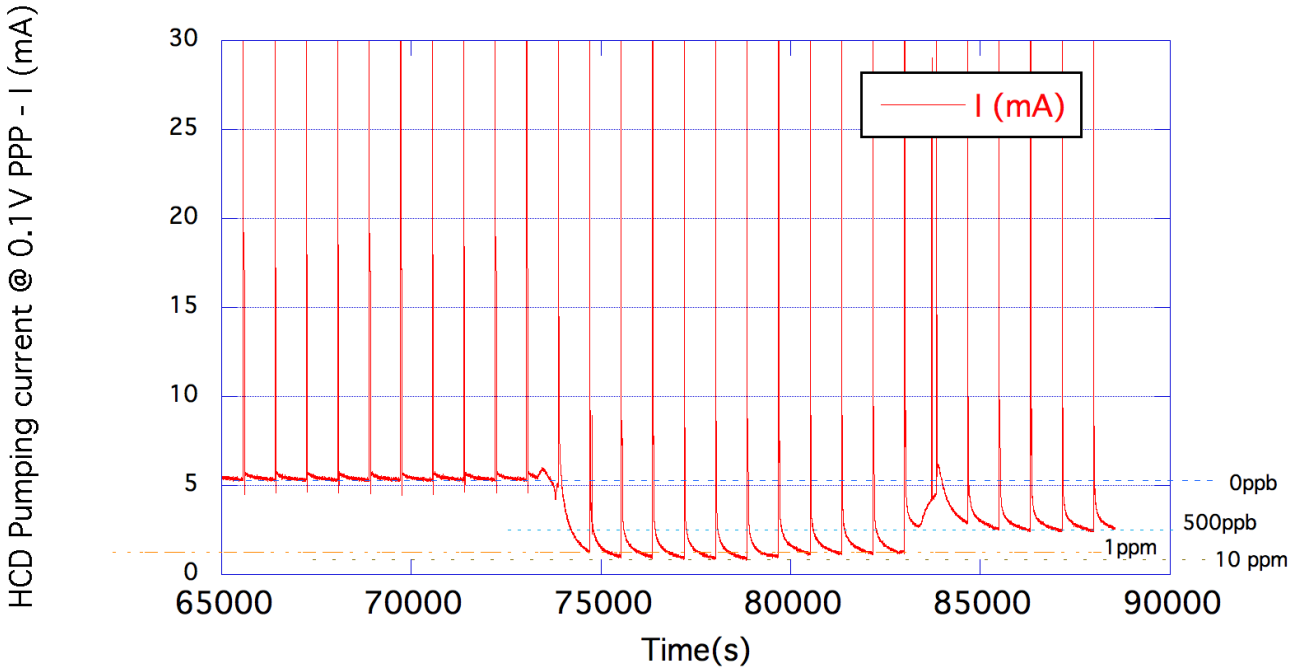

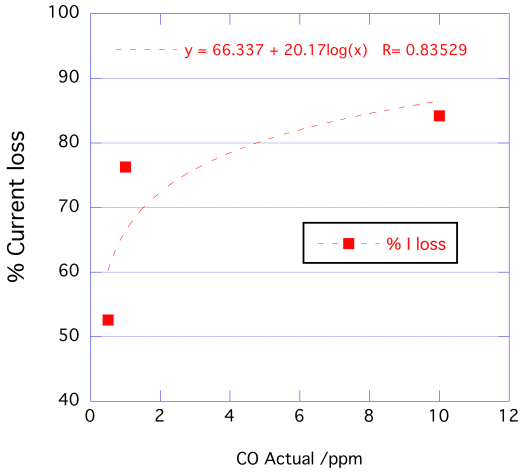

- Pulsed voltage protocol applied to HCD using new HCD controller mimics the data collected using the Gamry Reference 600+ potentiostat without introducing excess noise and loss of resolution.
- Data logging interval may be adjusted by operator.
- HCD current loss is proportional to [CO] as we have shown in previous work. Use a certain current value to trip relay.

HCD Temperature control of the new, pre-commercial hardware.

- Field test at Burbank: HCD and Gamry unit were placed inside refrigerated enclosure already onsite.
- Southern LA environment – high T due to solar heating: unrefrigerated enclosures can reach 120°F or more (safety sensor field testing).
- HCD baseline is most accurate with stable baseline pumping current: HCD is an electrochemical device!
- **A TE Tech Bi-polar Peltier cooler/heater system chosen for future field tests.**
- **Increases flexibility in locating/integrating the HCD system at future filling stations.**
- Off the shelf and not very expense.

CP-031 Peltier-Thermoelectric Cold-Plate Cooler

- Heats as well as cools (when used with heat & cool / bipolar controller).

TE Technology;
www.tetech.com

Standalone controller OR computer controlled versions available. The computer programmed modules are ½ the price of the display models.

HCD Complete System now undergoing testing at LANL

- Peltier thermal management system combined with HCD using a machined aluminum coupling plate for efficient heat transfer.
- Testing and optimization work ongoing:
  - New GDL for water wicking from internal reservoir
  - Compression of Ti plates
  - PID settings and insulation design around HCD
  - Selection of best pumping protocol
  - Relay control function
  - Modifications to VI program still required

- **Goal is an "open the box and turn-key" system" to move forward with new field tests in 2021.**
- **All station provider must supply is Internet and 100sccm of sample hydrogen gas.**

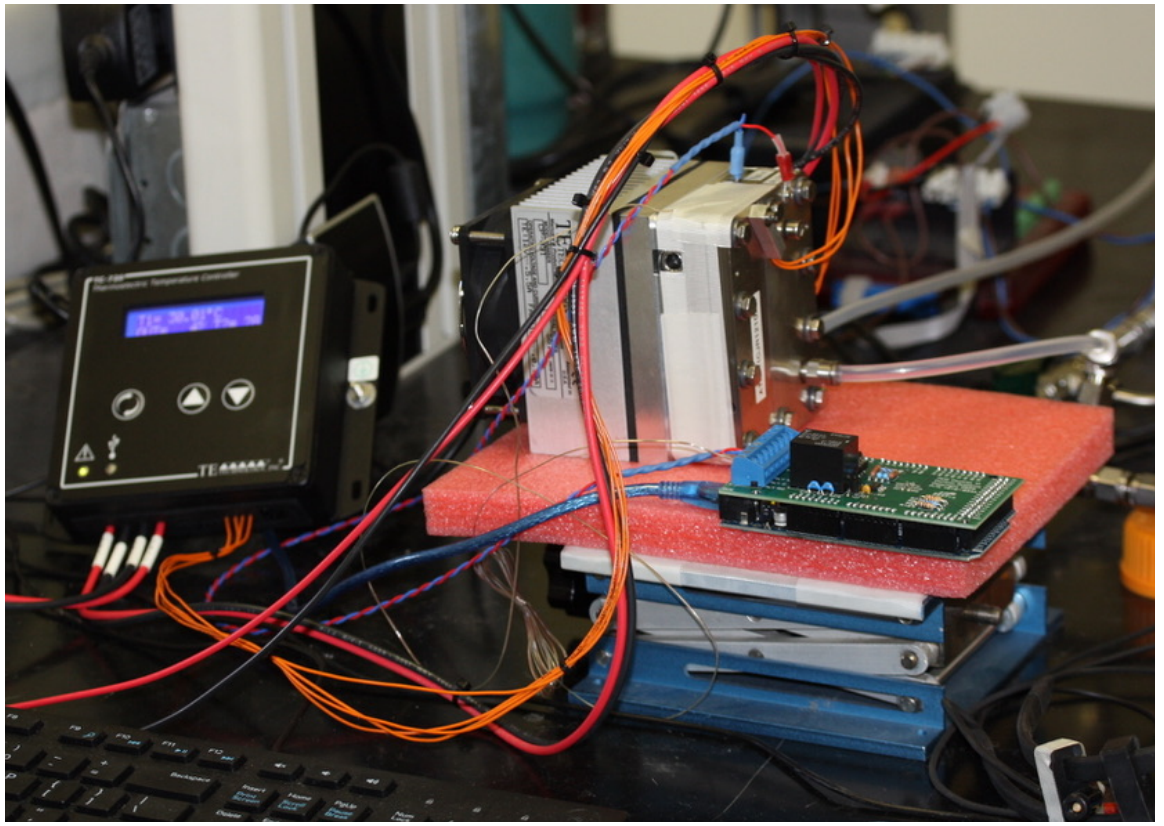

Photo shows new HCD system without thermal insulation.

HCD Complete System now undergoing testing at LANL

- **Present estimated retail cost, not including labor, recently estimated to be $4215/system.**
- **Compare to previous system field-tested at Burbank H2F which cost $22,500 not including the cost of the required refrigerated instrument cabinet.**

✓ Machined Ti HCD plates: $400/set

✓ Membrane/GDLs/GDE WE/CE: ~$50ea

✓ Peltier thermal module: $175

✓ Peltier controller: $750

✓ Machined Al adapter plate: $~240ea

✓ VI Controls HCD controller: $2500ea

✓ Misc: ~$100/unit

- **Does not consider volume production. HCD controller estimated to have ~$100 in parts.**